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This is a U.S. Patent Application for:

TITLE: **SYSTEM AND METHOD FOR IMPROVING MODEM TRANSMISSION THROUGH PRIVATE BRANCH EXCHANGES, CENTRAL OFFICES, AND OTHER SYSTEMS**

Inventor #1: William J. Beyda
Address: 21580 Edward Way, Cupertino, California 95014
Citizenship: USA

Inventor #2: Shmuel Shaffer
Address: 1211 Cowper Street, Palo Alto, California 94301
Citizenship: USA

SYSTEM AND METHOD FOR IMPROVING MODEM TRANSMISSION THROUGH PRIVATE BRANCH EXCHANGES, CENTRAL OFFICES, AND OTHER SYSTEMS

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BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to communications systems and, in

10   particular, to a system improving modem transmission by adjusting the modem's echo cancellation scheme based on the connection type.

DESCRIPTION OF THE RELATED ART

Digital communications systems take analog signals and digitize them,

15   pass them through the system, and convert them back into analog form. The digital-to-analog (D/A) and analog-to-digital (A/D) conversions can cause discontinuities in the communications link known as "echo." Such echoes represent an undesired or interfering signal to the receiver in the modem. Echoes are typically classified as near-end or far-end echoes. Near-end

20   echoes are reflections which normally occur relatively close in distance and not delayed too long in time relative to the transmitting modem. Far-end echoes are reflections which are remote, usually in distance and time, to the transmitting modem and typically occur at the remote modem. In particular, a digital-to-analog conversion at the transmitting modem can cause a near-end

25   echo (relative to the transmitting modem), and an analog-to-digital conversion at the receiving modem can cause a far-end echo.

Conventional echo cancellation schemes assume that there is only one D/A and A/D conversion in each connection, that is, there is only one switching device performing such conversions in the link between the

30   transmitting and receiving modems. Such a scenario is illustrated in FIG. 1. As shown, a telecommunications system 100 includes a modem 102a and a modem 102b. Modem 102a and modem 102b communicate via a switch 104. Assuming modem 102a is transmitting, an A/D conversion takes place between modem 102a and the switch 104, and a D/A conversion takes place

between the switch 104 and the modem 102b. The A/D conversion can cause near-end echo, and the D/A conversion can cause far-end echo.

Conventional echo cancellation schemes look for echo under 50 milliseconds in near-end echo cancellation circuitry, and echo of 100-150

5   milliseconds for far-end echo cancellation. If additional echo is introduced intermediate to either of the modems and the switch, conventional echo cancellation schemes can fail. While echo cancellation schemes are known which attempt to converge on intermediate echo, such schemes do not anticipate multiple far-end echo sources. For example, an echo cancellation

10   scheme described in U.S. Patent No. 4,970,715 looks for a most-dominant line echo, which may be a far-end or an intermediate echo. The system described then cancels the detected echo. However, the system assumes that there is only one non-near-end echo source.

15   **SUMMARY OF THE INVENTION**

These and other drawbacks in the prior art are overcome in large part by a system and method for echo detection and cancellation according to the present invention. A modem according to one implementation of the present invention includes an echo canceller adapted to determine locations of far-end

20   echo sources. The echo canceller is adapted to send a signal to turn off network echo suppressors and enter a training mode. A training signal at a predetermined modem training frequency is sent from the modem to the second modem in the link. The return signal is then sampled by the sending modem. Any far-end echoes manifest themselves as sine waves at the

25   modem training frequency, delayed in time. The time difference between the peak of the training signal and the echo signals is used to determine the echo delay.

A better understanding of the invention is obtained when the following detailed description is considered in conjunction with the following drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of a modem-to-modem communication path;

FIGs. 2A-2C are diagrams of other modem-to-modem communication paths;

FIG. 3 is a diagram illustrating echo signals according to an embodiment of the invention;

5   FIG. 4 is a diagram of an echo canceling modem according to an embodiment of the invention;

FIG. 5 is a diagram of an echo canceller according to an embodiment of the present invention; and

FIG. 6 is a flowchart illustrating operation of an embodiment of the

10   invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGs. 1-6 illustrate an improved system and method for echo cancellation. A modem according to an implementation of the invention

15   includes an echo canceller configured to adaptively identify and cancel plural sources of far-end echo.

FIGs. 2A-2C illustrate exemplary modem-to-modem configurations in which the teachings of the present invention are applicable. Shown in FIG. 2A is a system 200 including a first modem 202a, a second modem 202b, a

20   private branch exchange (PBX) 204, and a central office (CO) 206. Analog lines 208, 210, and 212 interconnect the modem 202a, the PBX 204, the CO 206, and the modem 202b, as shown. Thus, an analog-to-digital conversion 214 and a digital-to-analog conversion 216 are required via the PBX 204, and an analog-to-digital conversion 218 and a digital-to-analog conversion 220 are

25   required via the CO 206. As will be explained in greater detail below, an echo canceller on the modem 202a is configured to identify echoes resulting from the A/D conversion 214, D/A conversion 216, the A/D conversion 218, and the D/A conversion 220.

FIG. 2B illustrates another modem-to-modem communication system

30   employing echo cancellation according to the present invention. Shown are a modem 230a, a PBX 232, a first CO 234, a packet network 238, a second CO 236, and a second modem 230b. An analog link 240 links the modem 230a

and the PBX 232; an analog link 242 links the PBX 232 and the CO 234; an analog link 244 links the CO 234 and the packet network 238; an analog link 248 links the packet network 238 and the CO 236; and an analog link 250 links the CO 236 and the modem 230b. Thus, an A/D conversion 302 and a

5   D/A conversion 304 are required via the PBX 232; an A/D conversion 306 and a D/A conversion 308 via required at the CO 234; an A/D conversion 310 and a D/A conversion 312 are required via the packet network 238; and an A/D conversion 314 and a D/A conversion 316 are required via the CO 236. An echo canceller according to the present invention is adapted to identify and

10   cancel echoes resulting from the A/D conversion 302, D/A conversion 304, the A/D conversion 306, the D/A conversion 308, the A/D conversion 310, the D/A conversion 312, the A/D conversion 314, and the D/A conversion 316.

A similar configuration is shown in the system of FIG. 2C. Shown are a modem 260a, a PBX 262, a first CO 264, a packet network 268, a second CO

15   266, and a second modem 260b. An analog link 270 links the modem 260a and the PBX 262; an analog link 272 links the PBX 262 and the CO 264; a digital T1 link 274 (or E1 link in other situations) links the CO 264 and the packet network 268; a digital T1 link 276 (or E1 link in other situations) links the packet network 268 and the CO 266; and an analog link 278 links the CO

20   266 and the modem 260b. An echo canceller according to the present invention is adapted to identify and cancel echoes resulting from the A/D conversion 318, D/A conversion 320, the A/D conversion 322, and the D/A conversion 324. It is noted that, while specific network topologies are shown, the invention is applicable to other configurations. For example, the packet

25   networks 238 and 268 discussed above could include telephony-over-LAN systems, or an analog link could be replaced with a DSL link. Thus, the figures are exemplary only.

More particularly, the echo cancellers according to the present invention are adapted to send a signal to turn off network echo suppressors

30   (not shown) and enter a training mode. A training signal at a predetermined frequency is sent from the first modem to the second modem. The return signal is then sampled by the sending modem. Any far-end echoes will

manifest themselves as sine waves at the modem training frequency, delayed in time. The time difference between the peak of the training signal and the echo signals is used to determine the echo delay.

Operation of an implementation of the invention is illustrated

5   schematically with reference to FIG. 3. In particular, FIG. 3 illustrates a modem training signal 370 and echo signals 372-378 of the same frequency which result during training of the configuration (for example) of FIG. 2A. That is, four echo sources (from two A/D and two D/A conversions) exist in the system, as described with reference to FIG. 2A. Each of the echo signals is

10 increasingly delayed and is of increasingly lower amplitude.

In operation, the modem 202a's echo canceller sends the training signal 370. The A/D conversion 214 causes the echo signal 372, delayed by time T1. The D/A conversion 216 causes the echo signal 374, delayed by time T2. The A/D conversion 218 causes the echo signal 376, delayed by

15 time T3. The D/A conversion 220 causes the echo signal 378, delayed by time T4. As will be explained in greater detail below, the modem 202a's echo canceller detects each of the echo signals by detecting their peaks (or relative peaks) and measuring their delay with respect to the primary signal.

Turning now to FIG. 4, an exemplary modem 350 implementing echo

20 cancellation according to an embodiment of the invention is shown. A modem transmitter 356 receives digital data 352 and provides modulated analog signal output signals to a hybrid 358 which couples the signals to a telephone line. A typical transmitter may include a phase encoder and a digital-to-analog converter. The modem 350 further includes an echo canceller 360

25 coupled to receive input data 352 and deliver a replica of the echo(s) contained in the receive signal. A summer 362 is coupled to accept the echo replica(s) from the echo canceller and subtract the echo from the receive signal, thereby canceling the echo contained in the receive signal. The output of the summation circuit 362 is further applied to the echo canceller 360 for

30 adjusting the delay period. The output of the summation circuit 362 is also provided to the receiver 364, which performs decoding and analog-to-digital conversion to output digital data 354.

FIG. 5 is a block diagram of the echo canceller. As shown, the echo canceller 360 includes a signal detection unit (SDU) 502, a timing unit (TU) 506, a delay unit (DU) 508, and a signal reproduction unit (SRU) 504. The signal detection unit 502 is adapted to detect peaks 400a, 400b (FIG. 3) of the

5   data signal 370, as well as the peaks 402a, 402b of echo signals 372, the peaks 404a, 404b of echo signals 374, the peaks 406a, 406b of echo signals 376, and the peaks 408a, 408b of the echo signal 378. The timing unit 506 includes a timer (not shown) for determining the times T1, T2, T3, and T4 between the data signal and the echo signals. The timer begins timing once

10   the primary peak of the return transmit signal is received; the times the echo peaks are detected are saved for echo cancellation later, for example, by the delay unit 508. Once the timing of the echo signals is determined, the correction can proceed based on the determined timing. In particular, the signal reproduction unit 504 reproduces the transmit signal at a delay

15   provided by the delay unit 508 which is then cancelled by the summation circuit 362. Thus, the echo canceller 360 provides to the summation circuit 362 replicas of the received echo signals delayed in time by the appropriately determined delays.
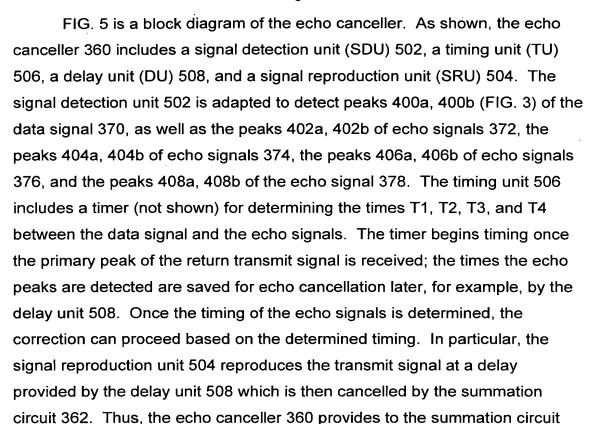
FIG. 6 is a flowchart illustrating operation of an embodiment of the

20   invention. In a step 602, a near-end modem transmits a modem training signal at a predetermined frequency. In a step 604, the sending modem receives the return signal from the remote modem. As described above, the receive signal includes the training signal, as well as one or more echo signals, representing near-end echo and one or more sources of far-end

25   echo. In a step 606, the signal detection unit 502 identifies a peak of the return transmit signal. In a step 608, the timing unit 506 activates a timer to time the period(s) to the next (echo) peak. In a step 610, the signal detector detects the echo peak or peaks. In a step 612, the timing unit 506 records the arrival time of the detected peak(s) of the echo signal(s). In a step 614, the

30   timing information is provided to the signal replication unit 504 and delay unit 508 for use in echo cancellation.

The invention described in the above detailed description is not

intended to be limited to the specific form set forth herein, but is intended to cover such alternatives, modifications and equivalents as can reasonably be included within the spirit and scope of the appended claims.